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ABSTRACT

This study investigated the grouping effect on student achievement in a chemistry laboratory when homogeneous and heterogeneous formal reasoning ability, high and low levels of formal reasoning ability, group sizes of two and four, and homogeneous and heterogeneous gender were used for grouping factors. The sample consisted of all eight intact chemistry classes of a medium-sized high school located in a university town in the southeast. Five laboratory experiments were conducted in each class. These experiments were organized to be open-ended so that procedure and work assignments could be determined by the group. The experiments covered the following topics: (1) indirect evidence; (2) density of liquids; (3) physical properties of ionic and covalent compounds; (4) freezing point determination; and (5) classification of common acids and bases. Included in this paper are the introduction and rationale, a literature review, the research protocol, results, conclusions, implications, and recommendations. (KR)

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THE EFFECT OF GROUPING BY FORMAL REASONING ABILITY, FORMAL REASONING ABILITY LEVELS, GROUP SIZE, AND GENDER ON ACHIEVEMENT IN LABORATORY CHEMISTRY

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INTRODUCTION AND RATIONALE

Science as a discipline differs from other subjects in the use of the laboratory as a vital component of the instructional method. Concepts and/or principles are merely presented in other subjects, but they may be illustrated, introduced, or verified with a science laboratory experiment. The purposes of the science laboratory are to support the lecture component, to teach laboratory skills, and to teach scientific inquiry. Rather than using the laboratory as verification for concepts, the laboratory should be a vehicle to teach generalizable skills which can be used to solve problems. Laboratory experience is important in influencing students to enter scientific careers (College Board, 1990).

Although laboratories were important, they were not as effective in improving science achievement as had been hypothesized in research studies. Many factors have been suggested as possible variables in laboratory effectiveness including student behavior in the laboratory (Bates, 1978). Kyle, Penick, and Shymansky (1979) recorded actual behaviors of students in introductory and advanced science laboratories. The recorded behavior for about half of the laboratory time was listening or reading.

Because science will have a greater importance in the future, varied methods of improving laboratory instruction should be investigated. One such approach would be to see if a more systematic and research-based approach to the formation of the laboratory groups and its possible effects upon student achievement in the science laboratory.

The purpose of this study to investigate the grouping effect on student achievement in a chemistry laboratory when homogeneous and heterogeneous formal reasoning ability, high and low levels of formal reasoning ability, group sizes of 2 and 4, and homogeneous and heterogeneous gender were used for grouping factors.

Hypotheses

The following null hypotheses were proposed:

1. There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups grouped homogeneously and heterogeneously for formal reasoning ability.
2. There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups with high formal reasoning ability and those with low formal reasoning ability.
3. There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups composed of two members and those with four members.
4. There will be no significant difference between

mean scores of laboratory achievement in high school chemistry between laboratory groups composed of homogeneous and heterogeneous gender groups.

5. There will be no significant differences among mean scores of laboratory achievement in high school chemistry when homogeneous and heterogeneous grouping for formal reasoning ability, formal reasoning ability levels, size of group, or gender composition of the group were considered as interacting variables.

LITERATURE REVIEW

Laboratories

One of the major points of disagreement among science educators is the purpose and function of laboratory work. Many educators think that scientific concepts should be introduced through laboratory experiences instead of lectures. If the laboratory is to be used to develop process skills, then it should be used for that purpose, but few laboratories are designed to do this (Tamir, 1989). Part of this disagreement arises from the definition of science itself. Science education should combine the two definitions, a collection of facts and a process (College Board, 1990). In a study at Bunker Hill Community College, Self, Self, and Self (1989) found students have little knowledge of the process of science.

For such a well-established teaching tool, the laboratory does not fare very well in research studies. Lehman (1989) asked students what they were doing, if they understood it, and what relationship laboratories had to the lecture classes. Many could not answer any of these questions. With the lack of positive evidence from research and from their own personal experiences, teachers (90% or more) are staying in their classrooms and lecturing 95% of the time (Bryant & Marek, 1987).

Hounshell (1989) recommends that demonstrations be substituted for laboratory experiments, until a safer, less crowded, more effective laboratory can be established. In a study by Glasson (1989) when demonstrations and hands-on laboratory experiments were tested, no differences in achievement were found, but laboratory students tested better on procedural knowledge. However, Beach and Stone (1988), under the auspices of the Institute for Chemistry Education (ICE), think laboratory is the essence of chemistry classes and state that the lack of laboratory work is one possible cause of the lowered status of U.S. science students worldwide.

In examining what actually occurs in a chemistry laboratory setting, Lehman's (1990) study found that 50% of the time was involved in questions and comments about directions and procedure. Of the remaining time only 10% was used for data collection and 10 % for qualitative analysis of the data. This study suggested that future research on laboratories should focus on individual differences and on methods to reduce procedure time and increase data analysis.

Formation of Laboratory Groups

Little attention has been directed toward the

formation and composition of laboratory groups. Marron (1975) excludes the possibility of repeating laboratory groups by using a Graeco-Latin Square for pairing partners. His findings indicate that left to student choice, the better students pair up leaving the poorer students to work together. Repeating pairs also may result in one partner being the worker, while the other does only what he/she is told.

Lawrenz and Munch (1984, 1985) used formal reasoning ability as a grouping method in two studies. Both studies examined the effect of grouping on formal reasoning ability and content achievement in physical science classes for preservice elementary teachers. Significant effects were found for both of the ability groups on content achievement with the homogeneous groups scoring higher. Homogeneous formal reasoning ability groups were most effective for gains in achievement and in formal reasoning ability.

Cooperative educators form all heterogeneous laboratory groups of mixed ability with 5 to 6 members, but stress a group responsibility approach. Each student is responsible for the understanding of the others in his/her group (Slavin, 1980).

Most laboratory group sizes are determined by class size divided by the number of laboratory stations with consideration to the amount of available equipment. Most collegiate settings used laboratory groups of two, while in high school laboratory groups of two or four are used (Lehman, 1989 and Marron, 1975).

Formal Reasoning

Formal reasoning ability has been found to be linked to the effective use of scientific reasoning. Formal reasoning is required in procedural knowledge to solve problems. Formal Piagetian reasoning is scientific reasoning according to Lawson (1982). Lawson cites a strong correlation between achievement and reasoning ability. In a later article Lawson (1985) affirms the conviction that schools must help students acquire thinking skills, not just teach concepts. Formal reasoning level is a predictor of science achievement if science is based on the ability to investigate and hypothesize. Despite Piaget's assumption of maturation at the age of 11 or 12, other studies show only 25% of 15- year-olds are formal thinkers. Aptitude and achievement are related to formal thinking, but they are not the same. Inquiry-oriented science enhances reasoning ability. Reasoning ability can be increased except for persons with limited mental capacities (Lawson, 1985).

In examining the benefits of laboratories, recent literature stems from the application of Piaget's scheme of cognitive development. For concrete learners science laboratory activities may play an outstanding role in achievement and cognitive development. A major emphasis of the Science Curriculum Improvement Study and other curriculum projects stresses that science is a process and the learner must be involved with concrete objects.

Based on these premises, a year long study was conducted by Saunders and Shepardson (1987) with a treatment using concrete instruction being compared with formal instruction. They reported significantly higher levels of performance in achievement and cognitive development in the concrete group. Those students classified as transitional on the pretest showed advancement to formal reasoning by year's end. Therefore, concrete instruction appears to be more successful in advancing thinking ability than formal instruction (Saunders & Shepardson, 1987).

Lawson and Thompson (1988) studied the elimination of biological misconceptions and concluded formal reasoning appears to contribute to the discarding of such misconceptions. They theorized that concrete thinkers may understand theories, but fail to apply them as a basis for generating hypotheses or predictions. Tobin and Capie (1982) found that formal reasoning ability was the strongest predictor of process skill achievement and retention. They theorized that formal reasoning ability is related to the rate of generalization and comprehension in middle school classes.

Howe and Durr (1982) in a study of chemistry classes used the combination of peer interaction with concrete models to enhance learning for transitional and formal operational students. Formal 15 to 17 year-olds used concrete operational structures in learning new concepts and learned best to understand abstract concepts with concrete objects. Learning improves when peer discussions take place. The difference between concrete and formal thinkers may be the ability to take the step from concrete models to abstract concepts. Even those with lower ability showed greater learning than their counterparts in traditional classes. In view of studies like this it is hard to justify a lecture-response method with an occasional demonstration as the principal method of secondary science instruction (Howe & Durr, 1982).

Gender Differences

de Hernandez, Marek, and Renner (1984) reported that males show a higher level of intellectual development that females for 16 to 17 year-olds. Males appear to mature intellectually earlier than females.

Kahle and Lakes (1983) reported that stereotyping discourages girls from science and scientific careers as early as kindergarten. Elementary teachers have different expectations for boys and girls. Parental expectations encourage girls toward fewer scientific career goals.

When girls and boys do experiments together, the boys do the work while the girls observe. A teacher might pair girls with girls and boys with boys to encourage girls to do more laboratory work. One solution is to give all children more opportunities to experiment. Newmann and Thompson (1987) also report on higher male participation and interaction in cooperative studies.

RESEARCH PROTOCOL

Problem

This study examined the grouping effect on student achievement in a chemistry laboratory when homogeneous and heterogeneous formal reasoning ability, high and low levels of formal reasoning ability, group size of 2 and 4 members, and homogeneous and heterogeneous gender were used for grouping factors.

Design

The design of the study was quasi-experimental pretest-posttest design. A total of eight groups was used. The independent variables were: grouping for formal reasoning ability, formal reasoning ability levels, size of group, and gender composition of the group. The dependent variables were the five posttests. The pretest on achievement served as a control for possible group differences. The instructional method of using cooperative groups was used for conducting the guided inquiry experiments. The statistical design was a 2x2x2 factorial analysis of covariance with the pretest serving as a covariant. Each posttest was analyzed with an individual analysis of variance. When significant interactions occurred, simple effects tests were done. A frequency distribution was collected from the Lawson's Classroom Test of Formal Reasoning Ability. Reliability was determined for the posttests with the Cronback's Alpha formula.

Sample

The sample consisted of all eight intact chemistry classes of a medium-sized high school located in a university town in the southeastern United States. The total number of students initially involved was 170. There were 91 males and 79 females with a racial breakdown of 98 white, 59 black, and 13 others. Ten students were dropped from the study due to absences and matching of the groups. The class sizes were 20, 21, 23, 20, 16, 22, 26, and 22. The majority of the students were juniors, but all of the classes included some sophomores and seniors. The eight classes were scheduled by computer at the year's beginning. It was assumed that due to the chance scheduling the composition of all the classes was similar. The classes were of mixed ability since chemistry is recommended to all college-bound students. The teachers of these classes were the researcher and the second chemistry teacher in the school.

Instrumentation

The classes were all given the test of formal reasoning ability developed by Lawson (1978). It consists of 15 items. This test was used because it measures concrete and formal operational reasoning, is capable of being used with secondary and college age students in a short amount of time, is easily scored, uses a format of physical materials with little reading

and writing, and has a large enough number and variety of problems to be reliable. Items selected for the test require the isolation and control of variables, probabilistic reasoning, correlational reasoning, and proportional reasoning. Each problem situation was demonstrated by the researcher in front of the classes while the students listened, wrote, and explained their answer. Credit was not given for unexplained answers. The test has a reported 0.78 coefficient of reliability using the Kuder-Richardson 20 formula. It has been judged to have validity by a panel of Piagetian experts. The form of the Lawson test used in this study omits the two items on combinatorial reasoning. It was modified by Lawrenz and Munch (1985) and a validity of 0.76 coefficient for reliability determined by the Kuder-Richardson 20 formula.

The student formal reasoning tests were scored by the researcher and each student was classified as having high or low formal reasoning ability. Students who scored from 7 to 13 were classified as having high formal reasoning ability. Students who scored 6 or less were classified as having low formal reasoning ability.

The pretest and posttest were identical. These were written by the researcher and approved by the assisting teacher. To check for content validity, they were submitted to two teachers with over 20 years of experience in teaching in the physical sciences and who are now teaching at the Mississippi School for Math and Science. In addition, they were reviewed by two science educators with experience in test construction and research for content and face validity. All judged the questions to be appropriate to the subject matter and grade level for which they were used. Reliability for the laboratory achievement test was found to be .80 as determined by Cronback's Alpha formula.

Subgroups

The variables in the study made the following groups possible:

1. Homogeneous FRA -2 members-homogeneous gender
2. Homogeneous FRA-2 members-heterogeneous gender
3. Homogeneous FRA-4 members-homogeneous gender
4. Homogeneous FRA-4 members-heterogeneous gender
5. Heterogeneous FRA-2 members-homogeneous gender
6. Heterogeneous FRA-2 members-heterogeneous gender
7. Heterogeneous FRA-4 members-homogeneous gender
8. Heterogeneous FRA-4 members-heterogeneous gender

Since there were eight classes, the teachers drew randomly the names of the subgroups from a hat and these names were assigned to classes 1 to 8 respectively. Using the previously determined formal reasoning ability scores, the teachers arranged the cooperative laboratory groups according to the drawn descriptions. In the homogeneous formal reasoning groups all of the group members were either of high or low ability. In heterogeneous groups one half of the group members had

high formal thinking ability and one half had low. In heterogeneous gender groups there were equal numbers of boys and girls. The homogeneous gender groups were either all boys or all girls.

Five laboratory experiments were conducted in each class. These experiments were organized to be open-ended so that procedure and work assignments could be determined by the group. The topics for the experiments were designed to cover the content of the first high school chemistry course. The first experiment, indirect evidence, used observations to draw conclusions. The second experiment, density of liquids, compared water, alcohol, and different molarities of salt solutions. The third experiment on ionic and covalent compounds allowed the student to discover the properties of these types of compounds. The freezing point of paradichlorobenzene, experiment number four, extended heat concepts and used graphing. The last experiment on acids and bases used various indicators to classify common and laboratory substances.

The pretest for all the experiments was given and scored as a control for possible initial group differences in achievement. The day preceding each laboratory was used as a pre-laboratory. Using the laboratory descriptions, the classes met as cooperative laboratory groups to plan their experiments and to determine how they would achieve the stated purposes. The descriptions contained a purpose and a list of equipment to help each group plan a procedure and their reports for the group. After a post-laboratory discussion was held on the day following the laboratory, the posttest was given. The pretests and posttests were administered individually to the the students, but group means were used in the statistical analysis of this study. Each cooperative group was responsible for one report and all students in the group were equally responsible for its content and received the same grade for its evaluation. The posttests and laboratory reports were evaluated by the teachers with the results being reported to the students at the end of the study. The pretest and posttest used in this study were scored by both teachers. When the grades were not identical, the score was found by averaging the two scores. A model grading guide for each pretest-posttest and laboratory report was formulated before the laboratories began.

RESULTS

Hypothesis 1

There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups grouped homogeneously and heterogeneously for formal reasoning ability. Based on the data obtained in this study, Hypothesis 1 was not rejected. Homogeneous and heterogeneous grouping according to formal reasoning ability produced no significant differences in terms of laboratory achievement.

Hypothesis 2

There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups with high formal reasoning ability and those with low formal reasoning ability. The null hypothesis was rejected in the composite study. The F value was 3.36 which is significant at the .01 level (see Table 2). In tables 6 to 8 formal reasoning ability was found to be significant at the .01 level in three of the five experiments: ionic and covalent compounds, freezing point of paradichlorobenzene, and classifying acids and bases. Students classified with high FRA scored significantly higher than students classified with low FRA.

Hypothesis 3

There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups of two members and those with four members. The size of the group was found to be significant at the .01 level in the composite study with a F value of 6.60. The null hypothesis was rejected (see Table 2). Smaller group size significantly increased laboratory achievement in 2 of the 5 experiments.

Hypothesis 4

There will be no significant difference between mean scores of laboratory achievement in high school chemistry between laboratory groups composed of homogeneous and heterogeneous gender groups. Gender grouping was found to be significant at the .05 level for the composite study with a F value of 2.27 (see Table 2). Homogeneous gender grouping significantly increased laboratory achievement in the overall composite analysis and in one experiment.

Hypothesis 5

There will be no significant difference among mean scores in laboratory achievement in high school chemistry when homogeneous and heterogeneous grouping, formal reasoning ability levels, size of group, and gender composition of the group are considered as interacting variables.

FRA Grouping x Size

The FRA grouping x size interaction was significant

TABLE 1

RELATIONSHIP OF COVARIATE TO DEPENDENT VARIABLE

VARIABLE	MULTIPLE R	R^2	F
INDIRECT EVIDENCE	.2501	.063	9.61**
DENSITY OF LIQUIDS	.1914	.037	5.48*
IONIC AND COVALENT	.3385	.114	15.57**
FREEZING POINT	.2655	.070	10.92**
ACIDS AND BASES	.4703	.221	40.90**

* p<.05 ** p<.01

TABLE 2

COMPARISON OF FRA GROUPING, SIZE, FRA LEVEL, AND GENDER COMPOSITION OF GROUPS ON OVERALL LABORATORY ACHIEVEMENT IN CHEMISTRY

SOURCES OF VARIANCE	CANON R	WILKES-LAMBDA	F
FRA GROUP (HOMOGENEOUS-HETEROGENEOUS)	.18	.93	.97
SIZE OF GROUPS (2 OR 4)	.44	.81	6.60**
FRA LEVEL (HIGH OR LOW)	.33	.89	3.36**
GENDER (HOMOGENEOUS -HETEROGENEOUS)	.27	.92	2.27*
FRA GROUP X SIZE	.24	.94	1.78
FRA GROUP X FRA LEVEL	.18	.97	.98
FRA GROUP X GENDER	.43	.81	6.49**
SIZE X FRA LEVEL	.33	.89	3.45**
SIZE X GENDER	.51	.74	9.82**
FRA LEVEL X GENDER	.18	.97	.96

*P<.05. **P<.01 (df = 1,144)

TABLE 3

ADJUSTED MEANS FOR MAIN EFFECTS

VARIABLE	FRA GROUP		SIZE		FRA LEVEL		GENDER	
	HOMO	HETER	TWO	FOUR	LOW	HIGH	HOMO	HETER
INDIRECT EVIDENCE	2.85	2.66	3.06	2.51	2.51	2.93	2.90	2.64
DENSITY	1.87	1.91	2.21	1.63	1.63	2.10	2.20	1.62
IONIC OR COVALENT	1.83	1.69	1.66	1.54	1.46	1.99	1.89	1.65
FREEZING POINT	2.67	2.49	2.66	2.52	2.17	2.91	2.84	2.36
ACIDS OR BASES	2.90	2.46	2.91	2.49	2.00	3.22	2.91	2.48

TABLE 4

FACTORIAL ANALYSIS OF VARIANCE MODEL FOR ACHIEVEMENT ON INDIRECT EVIDENCE

SOURCE OF VARIATION	MEAN SQUARE	F
FRA GROUP (HOMOGENEOUS OR HETEROGENEOUS)	.43	.56
SIZE OF GROUP (2 OR 4)	9.97	13.05*
FRA LEVEL (HIGH OR LOW)	.48	.63
GENDER (HOMOGENEOUS OR HETEROGENEOUS)	.97	1.27
FRA GROUP X SIZE	4.33	5.67*
FRA GROUP X FRA LEVEL	.14	.19
FRA GROUP X GENDER	14.43	18.76*
SIZE X FRA LEVEL	1.00	1.31
SIZE X GENDER	20.30	26.59*
FRA LEVEL X GENDER	.01	.01

*P<.01 (df= 1,159)

TABLE 5

FACTORIAL ANALYSIS OF VARIANCE MODEL
FOR ACHIEVEMENT ON DENSITY OF LIQUIDS

SOURCE OF VARIATION	MEAN SQUARE	F
FRA GROUP (HOMOGENEOUS OR HETEROGENEOUS)	.74	.70
SIZE OF GROUP (2 OR 4)	11.16	10.65*
FRA LEVEL (HIGH OR LOW)	1.15	1.09
GENDER (HOMOGENEOUS OR HETEROGENEOUS)	9.10	8.67*
FRA GROUP X SIZE	.08	.08
FRA GROUP X FRA LEVEL	.51	.49
FRA GROUP X GENDER	9.44	9.01*
SIZE X FRA LEVEL	.67	.65
SIZE X GENDER	17.41	16.61*
FRA LEVEL X GENDER	.32	.30

*P<.01 (df= 1,159)

TABLE 6

FACTORIAL ANALYSIS OF VARIANCE MODEL FOR ACHIEVEMENT
ON IONIC AND COVALENT COMPOUNDS

SOURCE OF VARIATION	MEAN SQUARE	F
FRA GROUP (HOMOGENEOUS OR HETEROGENEOUS)	.37	.49
SIZE OF GROUP (2 OR 4)	2.40	3.21
FRA LEVELS (HIGH OR LOW)	3.16	4.22*
GENDER (HOMOGENEOUS OR HETEROGENEOUS)	.43	.57
FRA GROUP X SIZE	.01	.02
FRA GROUP X FRA LEVEL	.46	.62
FRA GROUP X GENDER	4.41	5.90*
SIZE X FRA LEVEL	.40	.53
SIZE X GENDER	.08	.11
FRA LEVEL X GENDER	.10	.13

*P<.05 (df= 1, 159)

TABLE 7

FACTORIAL ANALYSIS OF VARIANCE MODEL FOR ACHIEVEMENT ON FREEZING POINT OF PARADICHLOROBENZENE

SOURCE OF VARIATION	MEAN SQUARE	F
FRA GROUP (HOMOGENEOUS OR HETEROGENEOUS)	.45	.26
SIZE OF GROUP (2 OR 4)	.12	.07
FRA LEVEL (HIGH OR LOW)	7.38	4.29*
FRA GROUP X SIZE	2.02	1.17
FRA GROUP X FRA LEVEL	.26	.15
FRA GROUP X GENDER	17.33	10.07**
SIZE X FRA LEVEL	3.98	2.31
SIZE X GENDER	.57	.33
FRA LEVEL X GENDER	.39	.22

*P< .05 . **P< .01 (df = 1, 159)

TABLE 8

FACTORIAL ANALYSIS OF VARIANCE MODEL FOR ACHIEVEMENT ON CLASSIFYING ACIDS AND BASES

SOURCE OF VARIATION	MEAN SQUARE	F
FRA GROUP (HOMOGENEOUS OR HETEROGENEOUS)	4.14	3.22
SIZE OF GROUP (2 OR 4)	2.63	2.05
FRA LEVELS (HIGH OR LOW)	19.38	15.08*
GENDER (HOMOGENEOUS OR HETEROGENEOUS)	.78	.61
FRA GROUP X SIZE	.19	.15
FRA GROUP X FRA LEVEL	.22	.17
FRA GROUP X GENDER	16.37	12.74*
SIZE X FRA LEVEL	4.36	3.39
SIZE X GENDER	.40	.31
FRA LEVEL X GENDER	4.08	3.18

* P< .01 (df =1, 159)

(F = 5.67) for the indirect evidence experiment at the .01 level (see Table 4). These data indicated that when FRA grouping was used, the homogeneous two member groups scored significantly higher than other groups.

FRA Grouping x FRA Levels

The FRA grouping x FRA levels interaction was not found to be significant in the composite study or in any of the individual experiment analyses (see Tables 2-8).

FRA Grouping x Gender Grouping

The FRA grouping x gender grouping interaction was found to be significant in the composite study at the .01 level with a F value of 6.49 (see Table 2). Each of the five individual experiments showed a significant interaction at the .01 level except the ionic and covalent experiment, which was significant at .016 level (see Table 4-8). From analysis of this data homogeneous gender groups achieved more than heterogeneous gender groups when working in homogeneous FRA groups. The result was obtained in the composite study and on each of the five individual experiments.

Size x FRA Levels

The size x FRA levels effect was found to be significant at the .01 level with a F value of 3.45 on the composite analysis (see Table 2). No significant interactions were found in the individual experiments (see Table 4-8). Examination of the adjusted means showed that in 3 of the 5 experiments high level FRA groups scored higher when working in groups of two (see Table 3).

Size x Gender Grouping

Size x gender was found to be significant at the .01 level with a F value of 9.82 in the composite analysis (see Table 2). As indicated on Table 4 the F value for this interaction on the indirect evidence experiment is 26.59 which is significant at the .01 level. In the density experiment the F value is 16.61 significant at the .01 level (see Table 5). From analysis of the data when homogeneous gender grouping was used, groups of four achieved significantly higher scores on laboratory achievement than groups of two.

FRA Levels x Gender Grouping

There were no significant interactions for FRA levels x gender (see Tables 2-8).

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Conclusions

Formal reasoning ability grouping (FRA grouping) did not produce a significant effect. There was no significant difference in laboratory achievement between the homogeneous FRA group and the heterogeneous FRA group.

Students classified with high formal reasoning ability scored significantly higher in laboratory achievement than those classified with low formal reasoning ability.

Students in groups of two members scored significantly higher in laboratory achievement than students in groups of four.

Students working in homogeneous gender groups scored significantly higher in laboratory achievement than those in heterogeneous gender groups.

An interaction between FRA grouping and size indicated homogeneous grouping of two member groups scored significantly higher than groups of four. Interactions between FRA grouping and gender indicated homogeneous FRA grouping of homogeneous gender groups scored significantly higher than heterogeneous gender groups. The size by FRA levels interactions indicated two member high formal reasoning groups score significantly higher than two member low formal reasoning ability groups. The size by gender interaction indicated homogeneous gender groups of four scored significantly better than heterogeneous groups of four.

Implications

Lawson (1985) proposed that increased formal reasoning ability levels would increase science achievement. In this study students with a higher FRA level achieved significantly higher laboratory achievement scores than students with lower formal reasoning ability. These results indicate science teachers should use instructional methods to increase formal reasoning ability. The exact relationship of formal reasoning ability to achievement in chemistry has not been defined. The studies of Howe and Durr (1982), Lawrenz and Lawson (1986), Saunders and Shepardson (1987) show that raising formal reasoning ability levels can be accomplished by specific teaching methods. The use of concrete models to increase formal thinking is recommended.

Working in smaller laboratory groups produces higher achievement for students than working in large groups. This allows more participation and requires more responsibility of all group members. This issue has not been studied by science investigators. Research on cooperative educations usually used 5 to 6 member groups Results from this study show this group size to be inappropriate for chemistry laboratories.

Homogeneous gender groups achieve more than heterogeneous gender groups. Research indicates females fail to take leadership roles when working with males and males may have different behaviors when working only with other males as compared to working in a mixed group. Females are forced to take leadership and responsibility in laboratory groups when working with

only other females. Gender grouping was studied in the Kahle and Lakes' (1983) study, and suggested increased female participation was obtained. This study supported the Kahle and Lakes' study. If increased female leadership and participation is desired, then grouping by gender groups can accomplish this objective.

The FRA grouping and size interaction indicated that homogeneous FRA groups achieved more when in two member groups. The interaction of group size and gender grouping indicated that homogeneous gender groups achieved more when in groups of four. The size by FRA levels interaction indicated high formal reasoners achieve more in groups of two. The FRA grouping by gender interaction indicates that if homogeneous FRA grouping is used, then homogeneous gender groups achieve more than heterogeneous gender groups.

By inference the best possible grouping would be a homogeneous FRA grouping, homogeneous gender, group of two members.

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